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Genetic signature in mineral nutrition in oil palm (*Elaeis guineensis* Jacq.): a new panorama for high yielding materials at low fertiliser cost

**J.Ch. Jacquemard¹, J. Ollivier², Erwanda³, Edyana Suryana³
and Pepep Permadi³**

¹PT Socfindo Medan / UR Oil Palm Breeding – Cirad Bios, PO Box 1254 – Medan 20001 – Sumatera Utara – Indonesia

²UR Performance of tree-crop-based systems – Cirad Persyst, TA B-34/02, Avenue Agropolis 34398 Montpellier Cedex 5 – France

³PT Socfindo Medan – PO Box 1254 – Medan 20001 – Sumatera Utara – Indonesia
Corresponding author: jacquemard@indosat.net.id

ABSTRACT

Significant differences in mineral nutrition have been demonstrated between progenies and main categories at PT Socfindo (Jacquemard et al, 2002). New set of investigation has been conducted based on larger genetic background. It includes 489 progenies observed in 25 genetic trials planted in Aek Loba Timur Project and 63 commercial blocs covering around 3500 hectares dispatched through all PT Socfindo estates. Leaf contents in major elements constitute important genetic signature that allows characterization and individualization of nutritional level of each ALT project families according their genetic background. Observations achieved on commercial blocs confirm the signature of ALT project derived commercial categories. Some large groups show very distinct characteristics in their nutrient levels such as:

- *Low Nitrogen – low Potassium*
- *Low Nitrogen – high Potassium*
- *High Nitrogen – low Potassium*

In addition, some high yielding families express specific behaviour linking Calcium to their Chlorine absorption, then limiting Potassium absorption. Relation-ship between all these elements is discussed. Providing of high yielding planting material more frugal in fertilizer input is discussed. This new panorama offered to research and oil palm sector is an added value on the way of sustainable palm oil.

INTRODUCTION

Many factors may affect oil palm leaf nutrient concentration and by the way, critical levels. Abundant literature is available for a large majority of them (Corley and Tinker, 2003). Soil and age appear to be mostly underlined. Effect of soil is generally proven in all oil palm cultivation areas for all major and minor elements (Foster and Prabowo, 1996, Ollagnier et al, 1987). In other hand, age is known to depress leaf mineral contents. It is the case for nitrogen, phosphorus, potassium and magnesium (Hartley, 1988; Caliman et al, 1994).

Effect of planting material has been investigated in several field experiments (Jacquemard et al, 2002). In 3 progeny trials planted at Aek Kwasan genetic bloc (PT Socfindo), testing duras from LM404D selfed, LM404D x DA10D and DA115D selfed origins crossed by teneras and pisiferas from LM2T selfed, significant differences in mineral leaf contents was proven for nitrogen, phosphorus, potassium and magnesium. From these trials and from an experiment implemented in nursery on (DA5D x DA3D) II x La Mé materials, significant differences between individual progenies were detected for the same elements.

In experiments ALCP61 and ALCP62 (N3P3K3 subdivided for Mg), implemented with two different planting materials: (DA5D x DA3D) x LM2T selfed and (DA5D x DA3D) x LM311P, different critical level has been demonstrated for Potassium and suspected for Phosphorus (Jacquemard et al, 2002).

This paper would like report new set of investigations based on larger genetic background including commercial planting materials. New results from ALCP61 and ALCP62 allowing possible way to produce planting materials combining high productivity and low fertiliser rate are submitted.

EXPERIMENTAL

MATERIALS

The studied planting material comes from three PT Socfindo sources:

- Aek Loba genetic bloc
- ALCP61 and ALCP 62
- Commercial planting material

Planted from 1995 to 2000, the Aek Loba genetic bloc (ALT Bloc) includes 489 progenies planted in 25 progeny trials (Jacquemard et al, 2001). These progenies could be aggregated within ancestor families: for A Group, 18 families are identified and 24 families for B Group

(Table 1). Comparison in continuity between trials is allowed through special network of repeated progenies (Table 2). In addition, classical standard crosses (LM2T x DA10D and LM2T x DA115D) are planted in 1997 and 2000.

TABLE 1: ANCESTOR FAMILIES TESTED AT AEK LOBA TIMUR GENETIC BLOCK

A Group origins	Ancestors	B Group Origins	Ancestors
Socfindo	BB126DxBB150D BB177DxBB129D BB206Dselfed		?xLM9T FR10 FR9
Dabou	DA10DxDA115D DA10DxDA3D DA115D II DA115Dselfed DA115DxDA3D DA300DxDA128D DA551DxDA767D DA5DxDA3D II DABOU	Illegitimate	LM2TxLM231T LM2TxLM269D LM426Tselfed LM430Tselfed
		Socfindo	BB85Tselfed BB85TxBB20P
Socfin x Dabou	LM269DxDA115D LM269DxDA128D LM404DxDA10D LM404DxDA3D	La Mé	LA ME LM10Tselfed LM2T II LM2Tselfed LM2TxLM10T LM2TxLM5T LM2TxSI10T LM5Tselfed LM5TxLM10T LM5TxLM2T LM5TxLM311P
Socfin	LM404Dselfed		
Angola x Socfin	TNR115xLM630D	Yangambi	LM238TxLM511P PO4157T (LM718Tselfed) LM718TxLM238T
		Nifor	PO1879TxPO1876T

Highlighted in yellow, families planted in commercial blocks that are used for analyse in commercial area.

TABLE 2: NETWORK OF REPEATED PROGENIES

	1995	1997	1998	1999	2000
1995	3	7	0	0	4
1997	7	21	8	2	6
1998	0	8	6	6	5
1999	0	2	6	4	2
2000	4	6	5	2	2

ALCP61 and ALCP62, set up side by side at the Aek Loba plantation (North Sumatra), with two types of planting material, are studying the effect of four fertilisers on mineral nutrition and production (Jacquemard *et al.*, 2002). The purpose is to deduce the most appropriate fertiliser schedules.

The first trial (ALCP 61) is planted with (DA5D x DA3D) x LM2T self material, the second (ALCP 62) with (DA5D x DA3D) x LM311P material. LM311P is a pisifera of LM6, an illegitimate progeny of LM2T. The trial was set up on palms planted in 1989.

The design comprises 3 factors N, P and K studied on 3 levels. N, P and K applications are in a ratio of 0, 1 and 3. The subdivision for magnesium was launched in 1997 (Table 3).

TABLE 3: FACTORS STUDIED (KG / PALM / YEAR)

	Level 0	Level 1	Level 2
Urea	0.0	1.0	3.0
Rock Phosphate	0.0	0.5	1.5
KCl	1.0	2.0	4.0
Dolomite CP 61		0.5	1.0
Dolomite CP 62	0.0	0.5	

At the same time as the genetic trials were established, numerous categories reproducing some of listed families (Table 1) were distributed across the 10 PT Socfindo oil palm estates in North Sumatra and Aceh provinces. Unfortunately all ancestor families tested at Aek Loba Timur genetic bloc have not been planted in commercial blocs, which allow comparison for some of them only.

METHODS

Nutritional status data are specifically obtained by leaf analyses. Cirad standard method of collection and analyse has been used (Ochs and Ollivin, 1977). Samples have been taken from leaf 17 and analysed at Cirad laboratory. Analysed elements are Nitrogen, Phosphorus, Potassium, Calcium, Magnesium, Chlorine and Boron.

On Aek Loba Timur genetic bloc (ALT), samples per progeny are taken every two years from 3 years old. To date, complete set of data is available for 3, 5 and 7 years old. Standard fertilisation tables have been used for all ALT trials from N0 to N3 applications. Detail of these fertilizer tables is given in annexe 1 for each year of planting. After that age, fertilisation is monitored trial per trial through nutritional status. Data are corrected from possible environmental and fertilisation effects through network of repeated progenies (see Table 2 above).

Statistical analyses done to evaluate ancestor effects have been done with XLSTAT ®. Pearson model of Factorial Analyse in main components has been selected.

On commercial blocks, annual sampling is carried out, as it serves as a steering tool for recommendation of manure, and in the same manner, annual analyses are also carried out on the experiments in order to monitor the effects of treatments on the palm nutrition.

Commercial fertilisation policy adopts a fixed fertilisation from yr 1 to yr 5. The same standard fertilisation table used for ALT Bloc has been also used for all the commercial blocks. Data for 3 years old from 63 commercial blocks planted in 9 different estates have been used or this study.

RESULTS

MINERAL NUTRITION IN AEK LOBA TIMUR GENETIC BLOC

Mineral nutrition at 3 years old

Table 4 gives general mean, standard errors and values exceeding deviation passing this standard error.

TABLE 4: GENERAL MEAN AND STANDARD ERROR AT 3 YEARS OLD

	Nitrogen	Phosphorus	Potassium	Calcium	Magnesium
Mean	2,943	0,167	0,904	1,149	0,230
STDev	0,086	0,004	0,121	0,149	0,034
m-s	2,858	0,163	0,782	0,999	0,196
m+s	3,029	0,172	1,025	1,298	0,265

Tables 5 and 6 summarize A group families results at 3 years old at ALT and in commercial blocs. Different colours underline average position of the families in their group:

- Above m + s: Dark green
- From m + s to m: Pale green
- From m to m – s: Pale yellow
- Below m – s: Yellow

TABLE 5: 3 YEARS OLD VALUES FOR A GROUP ORIGINS AT ALT BLOC

Sub-Group	A origin	N	P	K	Ca	Mg
AN x Socfin	(TNR115xLM630D)I	3,054	0,166	1,021	1,069	0,191
Socfindo	BB126DxBB150D	2,877	0,173	1,166	0,910	0,207
Socfindo	BB177DxBB129D	2,892	0,167	1,062	0,986	0,190
Socfindo	BB206Dselfed	2,862	0,169	1,101	0,966	0,205
Dabou	(DA5DxDA3D)selfed	2,966	0,169	0,855	1,177	0,257
Dabou	DA 10 D	2,964	0,169	0,989	1,125	0,194
Dabou	DA10DxDA3D	2,983	0,167	0,892	1,100	0,217
Dabou	DA10DxDA115D	2,957	0,167	0,865	1,228	0,236
Dabou	DA 115 D	3,035	0,168	0,789	1,342	0,242
Dabou	DA115D II	2,901	0,165	0,866	1,333	0,215
Dabou	DA115Dselfed	2,994	0,168	0,813	1,276	0,238
Dabou	DA115DxDA3D	3,002	0,167	0,773	1,240	0,233
Socfin x Dabou	LM269DxDA115D	2,950	0,169	0,850	1,257	0,212
Socfin x Dabou	LM269DxDA128D	2,919	0,166	0,900	1,070	0,270
Dabou	DA300DxDA128D	2,891	0,168	0,888	1,097	0,221
Dabou	DA551DxDA767D	2,918	0,163	0,757	1,244	0,277
Socfin	LM404Dselfed	2,869	0,166	0,916	1,097	0,233
Socfin x Dabou	LM404DxDA10D	2,929	0,165	0,914	1,125	0,215
Socfin x Dabou	LM404DxDA3D	2,937	0,169	0,925	1,072	0,203

TABLE 6: 3 YEARS OLD VALUES FOR A GROUP ANCESTOR FAMILIES IN COMMERCIAL BLOCKS

Sub-Group	A origin	N	P	K	Ca	Mg
Dabou	DA115D x (DA5D x DA3D)	2,83	0,178	1,12	0,880	0,265
Dabou	DA115Dselfed	2,88	0,174	0,98	0,847	0,305
Dabou	DA5D x DA3D	2,89	0,176	1,02	0,808	0,291
Socfin x Dabou	(DA5D x DA3D) x (LM404DxDA10D)	2,89	0,174	0,99	0,823	0,281
Socfin x Dabou	LM404D x (DA5D x DA3D)	2,81	0,178	0,97	1,045	0,250
Socfin x Dabou	LM404D x DA10D	2,87	0,175	1,03	0,915	0,285
Socfin x Socfin	LM404D x LM270D	2,91	0,190	1,09	0,765	0,345
Socfindo	BB126DxBB150D	2,84	0,182	1,10	0,890	0,275
Socfindo	BB206Dselfed	3,02	0,186	1,06	0,981	0,276
	General Mean	2,88	0,179	1,04	0,884	0,286
	Standard Deviation	0,06	0,006	0,06	0,087	0,027

Ancestor families that are not represented at ALT Bloc are highlighted in blue – green.

Tables 7 and 8 summarize B group families results at 3 years old at ALT Bloc and in commercial blocs.

TABLE 7: 3 YEARS OLD VALUES FOR B GROUP ORIGINS AT ALT BLOC

Sub Group	B origin	N	P	K	Ca	Mg
LM	LM 2 T	2,992	0,168	0,909	1,212	0,213
LM	LM2Tselfed	2,967	0,166	0,888	1,176	0,212
LM	(LM2T)II	2,999	0,170	0,893	1,135	0,215
LM	LM2TxLM10T	3,025	0,169	0,854	1,181	0,219
LM	LM2TxLM5T	2,986	0,167	0,900	1,176	0,215
LM	LM5TxLM2T	2,866	0,167	0,928	1,122	0,207
LM	LM5Tselfed	2,929	0,166	0,799	1,255	0,234
LM	LM5TxLM311P	2,915	0,164	0,845	1,227	0,265
LM	LM5TxLM10T	2,953	0,168	0,833	1,155	0,225
LM	LM10Tselfed	2,988	0,167	0,840	1,250	0,229
LM x SI	(LM2TxSI10T)I	2,965	0,172	0,970	1,065	0,224
SOCFINDO	BB85Tselfed	2,902	0,174	1,161	0,900	0,227
SOCFINDO	BB85TxBB20P	2,860	0,172	1,215	0,864	0,201
YA	LM238TxLM511P	2,912	0,166	0,904	1,069	0,259
YA	LM718TxLM238T	2,893	0,171	1,044	0,980	0,241
YA	PO 4157 T	2,788	0,164	0,956	1,055	0,198
NIFOR	PO1879TxPO1876T	2,861	0,170	1,191	0,947	0,193
Other	PO 3660 P	2,778	0,153	0,935	1,057	0,287
Other	BB 106 T	2,687	0,163	1,075	0,894	0,163
Other	FR10	2,851	0,163	0,739	1,348	0,257
Other	?xLM9T	2,876	0,166	0,839	1,074	0,232
Other	FR9	2,891	0,165	0,836	1,302	0,259
Other	LM426Tselfed	2,944	0,168	0,950	1,219	0,231
Other	LM2TxLM231T	3,044	0,175	0,817	1,250	0,309

TABLE 8: 3 YEARS OLD VALUES FOR COMMERCIAL PLANTING MATERIAL

Sub-Group	B origin	N	P	K	Ca	Mg
La Mé	LM2T selfed	2,88	0,175	1,00	0,848	0,285
La Mé	LM5T selfed	2,91	0,179	0,99	0,841	0,286
La Mé	LM5T x LM311P	3,01	0,176	0,88	0,940	0,295
Yangambi	LM718T selfed	3,02	0,186	1,06	0,981	0,276
Yangambi	LM718T x LM238T	2,88	0,187	1,09	0,807	0,322
	General Mean	2,94	0,181	1,01	0,883	0,293
	Standard Deviation	0,064	0,006	0,082	0,073	0,018

LM718T selfed is not represented in ALT Bloc series. PO4157T not presented in table (cross tested in ALT genetic trial) is a tenera coming from LM718T selfed but it cannot be considered as representative of the selfing.

Mineral nutrition at 5 – 7 years old

Tables 9 to 11 deliver equivalent information for 5 – 7 years old results.

TABLE 9: GENERAL MEANS AND STANDARD ERROR AT 5 – 7 YEARS OLD

	Nitrogen	Phosphorus	Potassium	Calcium	Magnesium	Chlorine	Boron
Mean	2,731	0,164	0,984	0,890	0,182	0,691	15,0
STDev	0,085	0,004	0,105	0,098	0,028	0,058	1,592
m-s	2,645	0,160	0,879	0,792	0,155	0,633	13,435
m+s	2,816	0,168	1,089	0,988	0,210	0,748	16,619

TABLE 10: 5 – 7 YEARS OLD VALUE FOR A GROUP ORIGINS

Sub-Group	A origin	N	P	K	Ca	Mg	Cl	B
AN x Socfin	(TNR115xLM630D)I	2,813	0,163	1,008	0,881	0,161	0,748	14,053
Socfindo	BB126DxBB150D	2,633	0,166	1,146	0,739	0,171	0,693	13,225
Socfindo	BB177DxBB129D	2,668	0,162	1,105	0,794	0,151	0,672	12,398
Socfindo	BB206Dselfed	2,660	0,165	1,165	0,782	0,160	0,706	12,916
Dabou	(DA5DxDA3D)selfed	2,744	0,165	1,008	0,910	0,194	0,683	15,483
Dabou	DA 10 D	2,776	0,163	1,074	0,858	0,162	0,697	14,4
Dabou	DA10DxDA3D	2,765	0,163	0,951	0,906	0,168	0,640	14,708
Dabou	DA10DxDA115D	2,745	0,162	0,950	0,936	0,182	0,682	15,623
Dabou	DA 115 D	2,828	0,163	0,915	1,019	0,195	0,742	16,6
Dabou	DA115D II	2,748	0,160	0,973	0,918	0,171	0,728	15,392
Dabou	DA115Dselfed	2,800	0,164	0,883	0,983	0,195	0,719	16,487
Dabou	DA115DxDA3D	2,711	0,161	0,867	0,979	0,172	0,662	15,754
Socfin x Dabou	LM269DxDA115D	2,751	0,164	0,951	0,921	0,180	0,670	15,921
Socfin x Dabou	LM269DxDA128D	2,648	0,161	0,942	0,903	0,207	0,618	15,540
Dabou	DA300DxDA128D	2,690	0,164	0,989	0,858	0,189	0,730	15,178
Dabou	DA551DxDA767D	2,737	0,157	0,714	1,032	0,260	0,672	17,248
Socfin	LM404Dselfed	2,685	0,166	0,950	0,902	0,186	0,672	15,157
Socfin x Dabou	LM404DxDA10D	2,754	0,166	0,970	0,912	0,181	0,683	15,825
Socfin x Dabou	LM404DxDA3D	2,752	0,168	0,967	0,879	0,164	0,674	14,662

TABLE 11: 5 – 7 YEARS OLD VALUE FOR B GROUP ORIGINS

Sub Group	B origin	N	P	K	Ca	Mg	Cl	B
LM	LM 2 T	2,797	0,163	1,011	0,922	0,175	0,715	15,3
LM	LM2Tselfed	2,773	0,164	0,973	0,898	0,170	0,710	15,329
LM	(LM2T)II	2,789	0,164	0,998	0,866	0,173	0,691	15,288
LM	LM2TxLM10T	2,773	0,164	0,937	0,933	0,170	0,686	15,536
LM	LM2TxLM5T	2,776	0,163	0,975	0,917	0,174	0,699	15,172
LM	LM5TxLM2T	2,726	0,167	1,048	0,881	0,151	0,756	14,138
LM	LM5Tselfed	2,730	0,164	0,886	0,982	0,187	0,705	16,505
LM	LM5TxLM311P	2,767	0,167	0,924	0,970	0,215	0,688	16,891
LM	LM5TxLM10T	2,741	0,164	0,915	0,915	0,182	0,713	14,938
LM	LM10Tselfed	2,792	0,164	0,936	0,973	0,171	0,696	15,702
LM x SI	(LM2TxSI10T)I	2,753	0,166	1,002	0,841	0,195	0,673	14,227
SOCFINDO	BB85Tselfed	2,630	0,167	1,136	0,725	0,183	0,680	13,961
SOCFINDO	BB85TxBB20P	2,619	0,166	1,216	0,706	0,172	0,722	13,820
YA	LM238TxLM511P	2,685	0,161	0,904	0,911	0,222	0,629	14,575
YA	LM718TxLM238T	2,636	0,164	1,040	0,826	0,195	0,664	13,852
YA	PO 4157 T	2,574	0,162	0,987	0,909	0,182	0,699	14,1
NIFOR	PO1879TxPO1876T	2,589	0,161	1,228	0,783	0,143	0,614	12,619
Other	PO 3660 P	2,486	0,150	1,055	0,804	0,185	0,593	13,7
Other	BB 106 T	2,587	0,164	1,097	0,737	0,135	0,704	12,4
Other	FR10	2,712	0,161	0,894	0,947	0,225	0,730	15,607
Other	?xLM9T	2,677	0,160	0,935	0,833	0,190	0,722	14,317
Other	FR9	2,638	0,159	0,919	1,003	0,213	0,640	16,368
Other	LM426Tselfed	2,736	0,162	0,979	0,932	0,182	0,679	14,106
Other	LM2TxLM231T	2,716	0,165	0,933	0,988	0,229	0,673	16,359

DISCUSSION

MINERAL NUTRITION

As explained above, all progenies planted in the trials received fixed fertilisation. Possible environmental fluctuations as soils fertility and few differences in fertilizer tables are stabilized through corrections done with repeated progenies. In this discussion, we do not include illegitimate origins detected in B group.

In commercial blocks, nutrient general means for both the group origins appear higher for Phosphorus, Potassium and Magnesium, even or lower in Nitrogen but very lower in Calcium compared to ALT bloc. It is to be noted that ALT genetic block is established on very calcic soils, which can explain the observed differences.

At 3 years old, there is any A or B group origin showing excess in phosphorus nutrition at ALT Bloc following Nitrogen – Phosphorus balance commonly accepted (Tampubolon *et al*, 1990). Some of them are presenting strong phosphorus deficiency (Figures 1 and 2, next page):

For A Group origins: all DA115D origins except LM269D x DA115D, LM404D x DA10D, DA551D x DA767D and TNR115 x LM630D.

For B Group origins: nearly all La Mé group is borderline of Deficiency 2 level. Two Yangambi origins are very low: PO4157T (from LM718T selfed) and LM238T x LM511P. BB85T selfed is borderline for excess of phosphorus leaf content.

Because of their better nutritional level in Phosphorus, the situation is different in commercial blocks and the N-P equilibrium is quite well balanced for both origins (Fig 2 and 3) and many of them even show Phosphorus excess. However, it is observed that the rank classifying the origins show similarities. For instance, in A group, BB206D self and BB126D x BB150D are amongst the highest, and DA115D or LM404D x DA10D amongst the lowest (Fig 2) which is also observed in ALT Bloc in Fig 1.

Same similarities in group B, where LM718T x LM238T is recorded in a better position compared to LM2T and LM5T x LM311P in Fig 4 are also ranked in the same order in Fig 2.

Total Leaf Cation content and Nitrogen balance (Figures 5 and 6), is explored according relationship proposed by Foster (2003). Many A Group origins are in borderline situation. Note that TNR115 x LM630D presents excessive high nitrogen leaf content and many families based on DA115D are under optimum N. However, this last figure does not appear

clearly in commercial blocs (Figure 7). Same observation could be delivered for B Group origins: many out of them are in borderline position except for LM5T Selfed and LM5T x LM311P (Figure 6). In commercial estates, LM5T x LM311P is in opposite position (Figure 8).

Calcium and Magnesium Cation balance is showing particular disequilibrium in general (detailed data in annexe). Magnesium balance is generally recorded below 21%. It seems very specific to Aek Loba Estate environment, when compared to commercial blocs where Mg / TLC is currently always above 21% as shown in annex. Some origins present notable excess in Calcium (balance above 60%): that is concerning all DA115D based origins from A group and LM5T selfed or LM10T selfed for B group. It appears that family behaviour could be specific to location as shown, again, when compared to results from commercial blocs.

At 5 – 7 years old (Figures 9 and 10), Nitrogen – Phosphorus balance appears improved at ALT Bloc. But for both origin groups, some families are still in deficiency 2. For A Group, are concerned DA115D itself, DA115D II, DA10D x DA115D, DA10D itself, DA551D x DA767D and TNR115 x LM630D. From B group, LM2T itself and LM238T x LM511P present this strong phosphorus deficiency. BB85T selfed and BB85T x BB20P show correct Nitrogen – Phosphorus nutrition.

Concerning Nitrogen – Total Leaf Cation balance, equilibriums seem slightly improved particularly for DA115D derived origins (Figure 11) in A group origins. TNR115 x LM630D is still presenting excess in nitrogen. In B group origin (Figure 12), families appear organized within two separate areas: origins belonging from Yangambi or related families presenting relatively too low nitrogen content compared to their Total Leaf Cation in one hand. In other hand, LM2T and LM10T deriving origins show higher nitrogen than expected. Specific mention should be done for LM5T selfed and LM5T x LM311P that are presenting lower nitrogen contents than expected.

Calcium balance is decreasing for A group origins from 56,7% to 52,9%; but in favour of potassium balance only that grow from 23,6 to 29,5%. Magnesium balance is still miserable. Same figure is recorded in similar evolution for B group origins.

Figure 1: Nitrogen - Phosphorus balance for A group origins at 3 years old

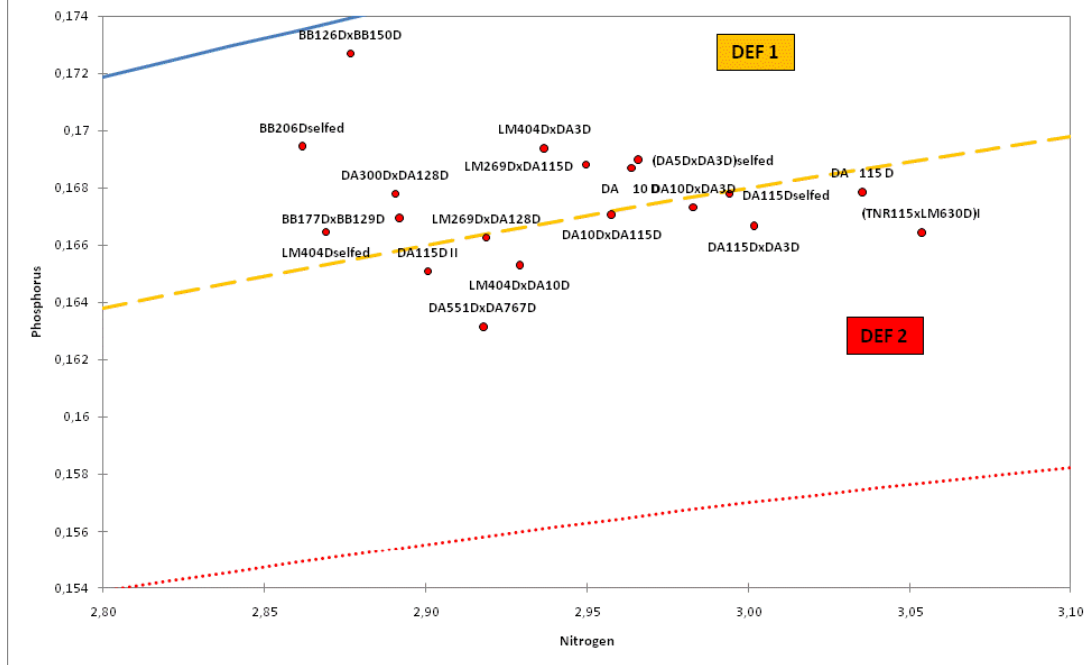
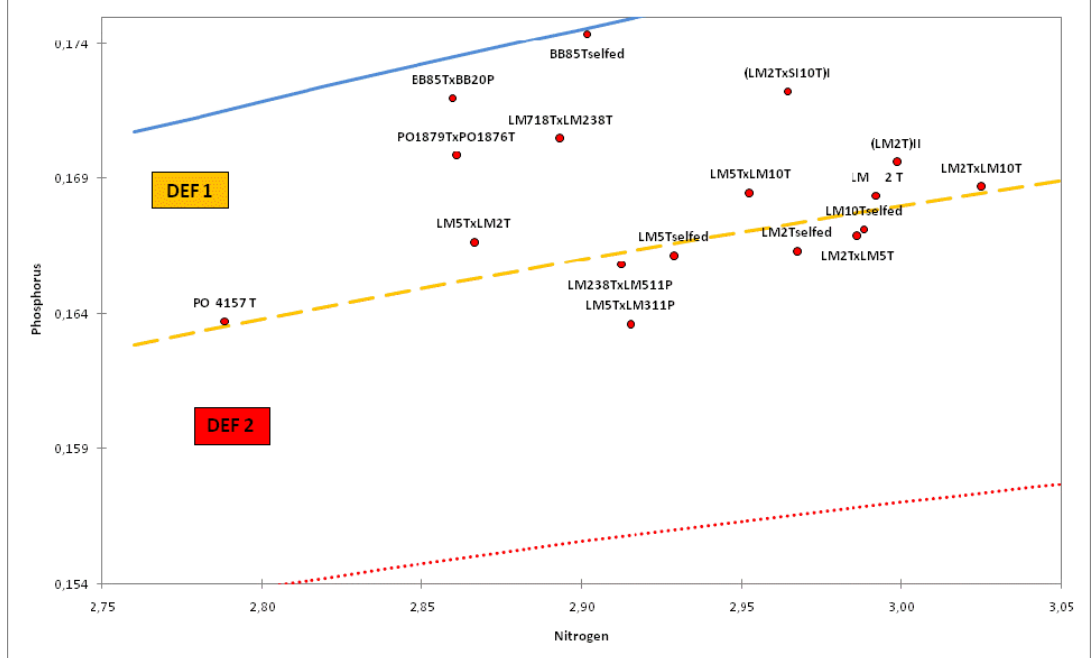
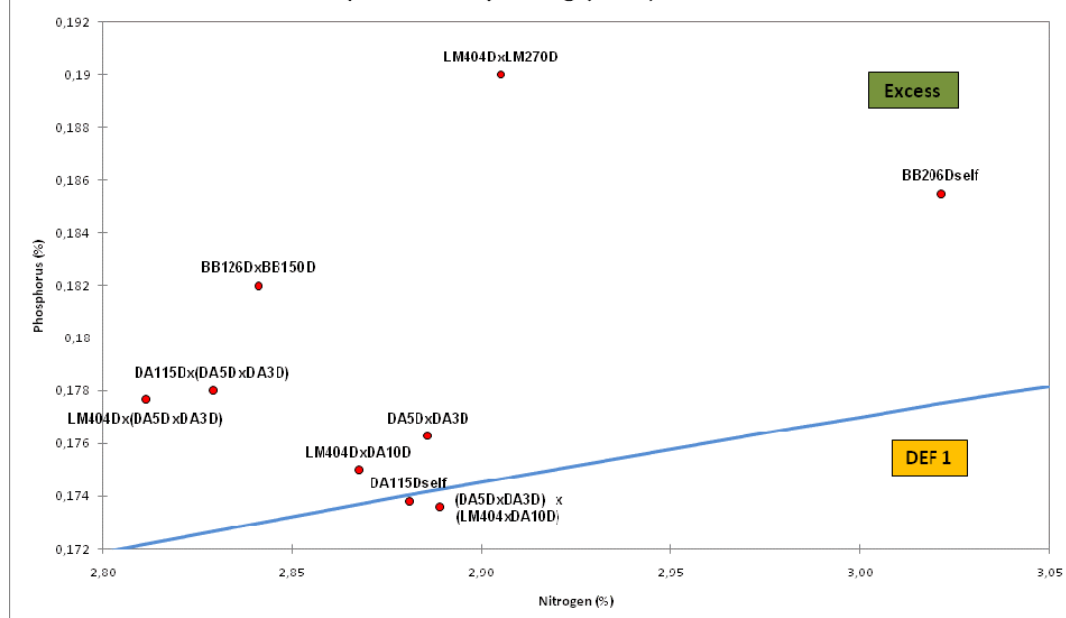


Figure 2: Nitrogen - Phosphorus balance for B group origins at 3 years old



**Figure 3: Nitrogen - Phosphorus balance for A group families
(commercial plantings) at 3 years old**



**Figure 4: Nitrogen - Phosphorus balance for B group families
(Commercial plantings) at 3 years old**

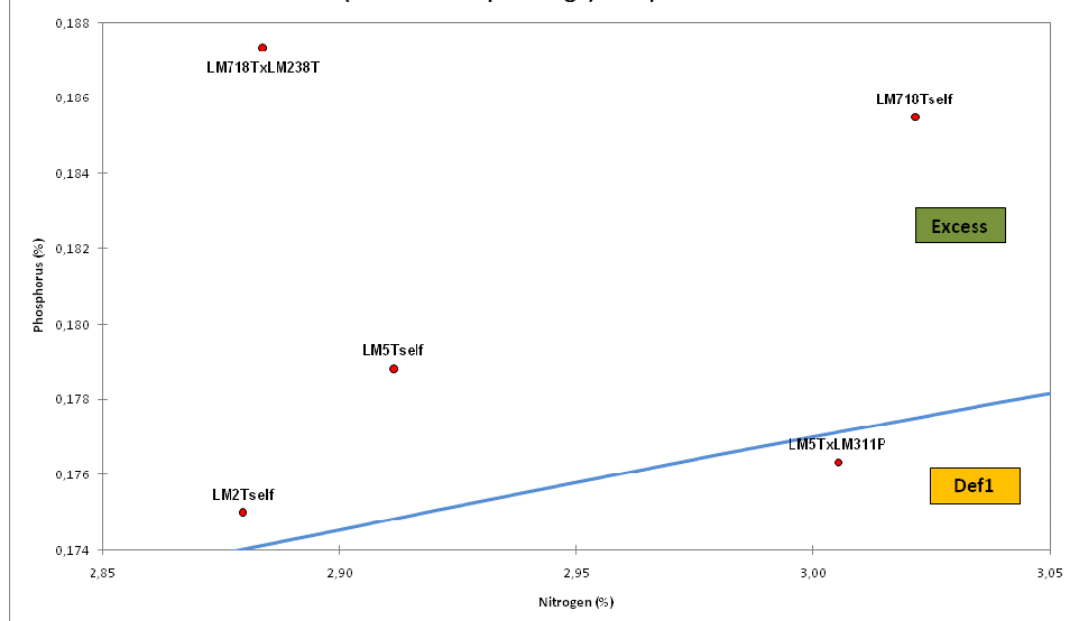


Figure 5: Nitrogen and Total Leaf Cation Content for A group origins at 3 years old

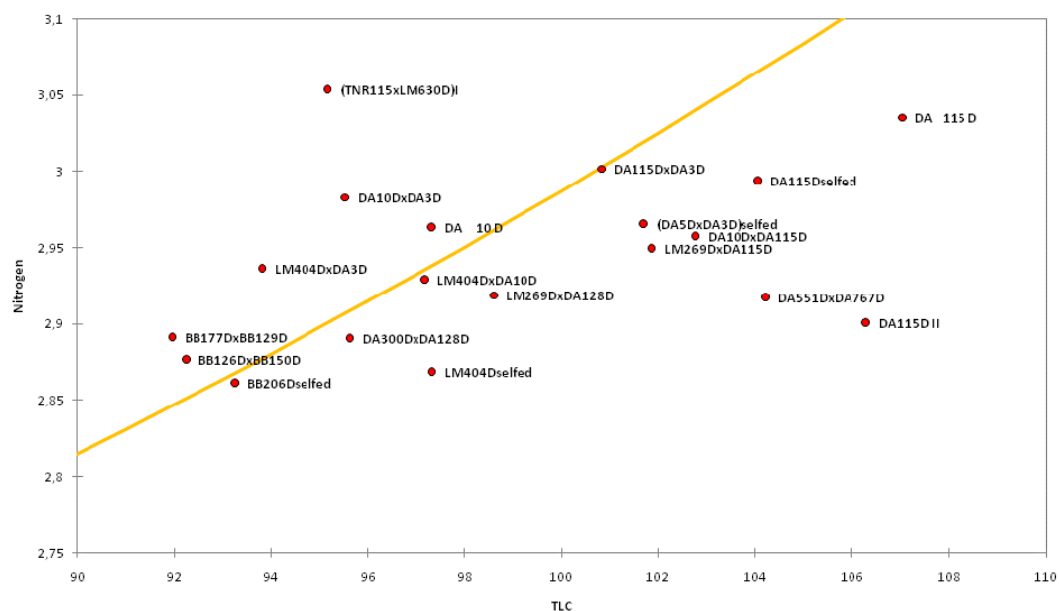
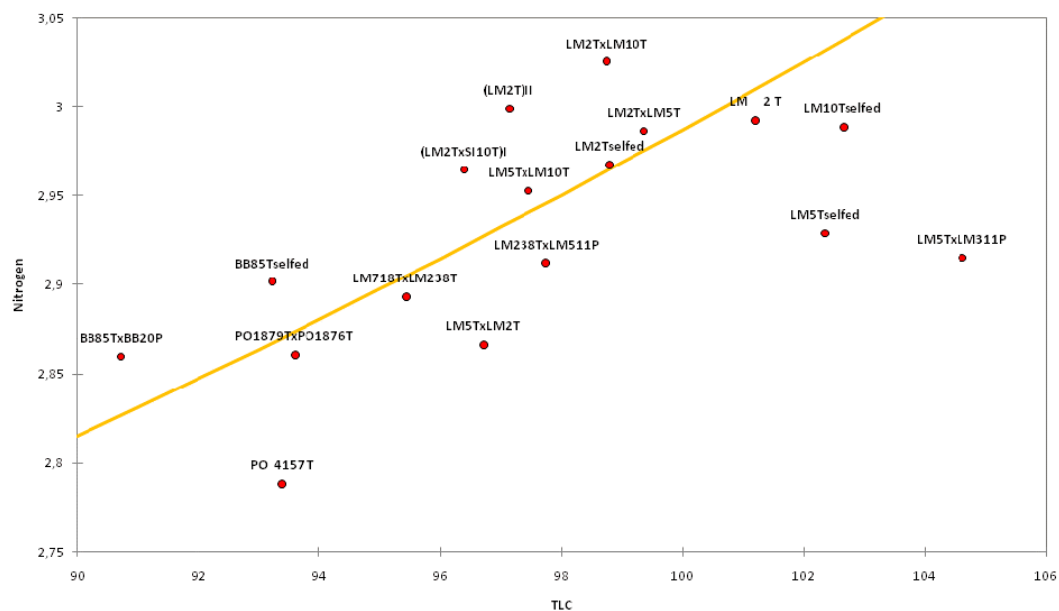
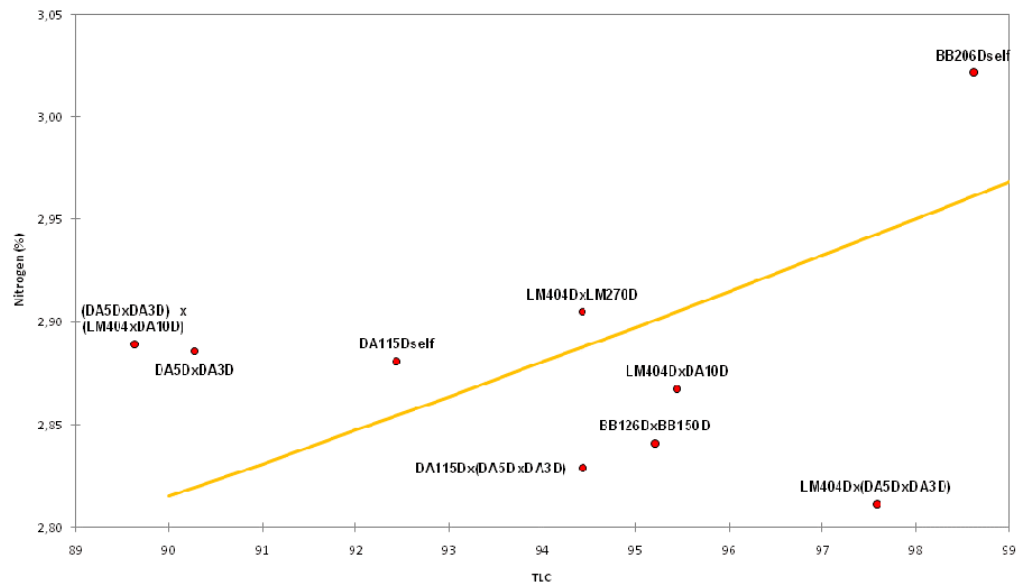


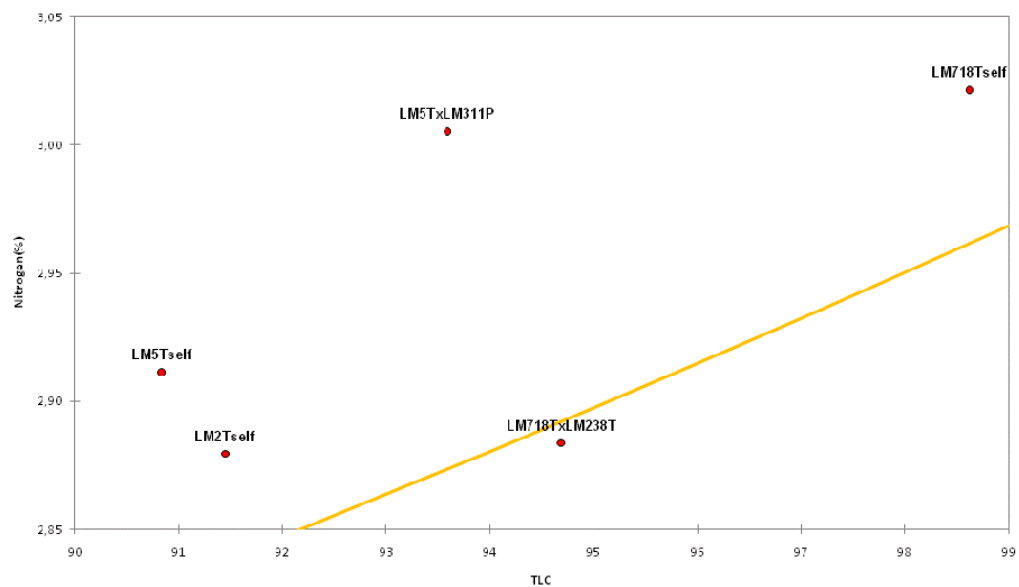
Figure 6: Nitrogen and Total Leaf Cation contents for B Group origins at 3 years old



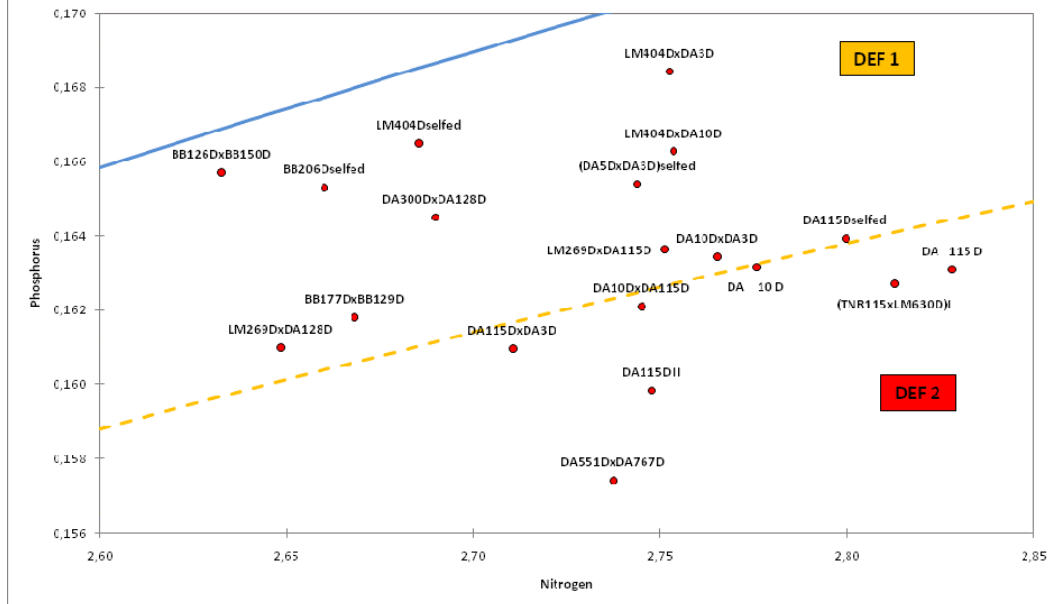
**Figure 7: Nitrogen and Total Leaf Cation contents for A group families
(Commercial plantings) at 3 years old**



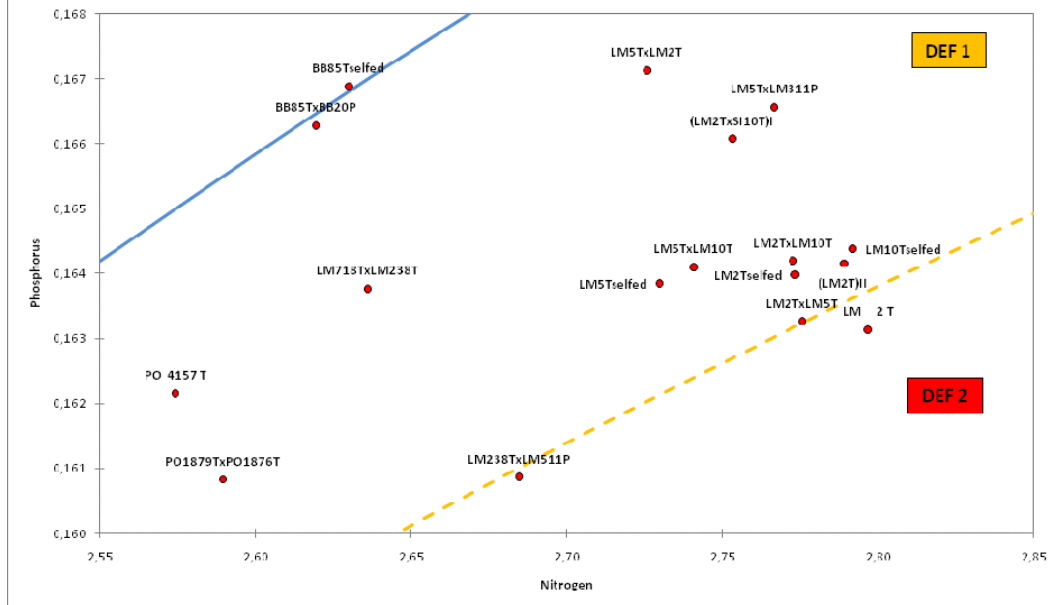
**Figure 8: Nitrogen and Total Cation Leaf content for B group origins
(Commercial plantings) at 3 years old**



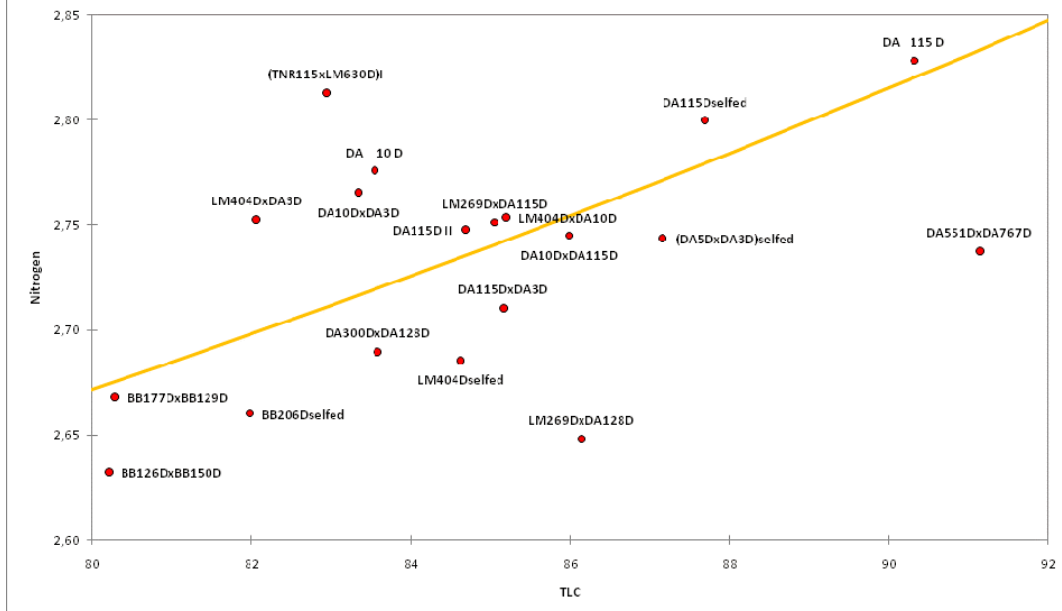
**Figure 9: Nitrogen - Phosphorus balance for ALT Bloc A group origins
at 5 - 7 years old**



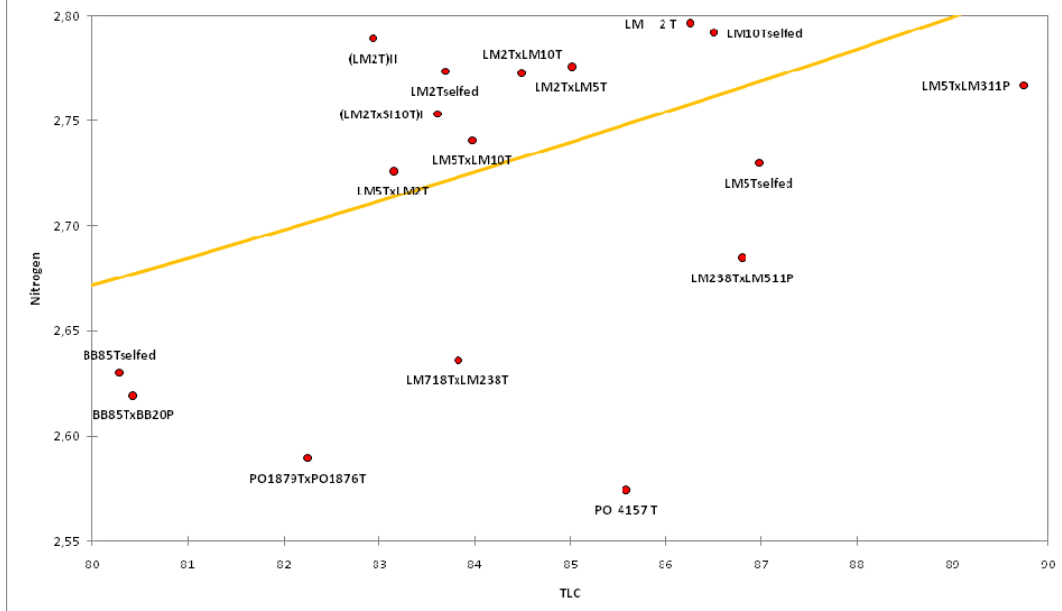
**Figure 10: Phosphorus deficiency for ALT Bloc B Group origins
at 5 - 7 years old**



**Figure 11: Nitrogen and Total Leaf Cation from A group origins
at 5 - 7 years old**



**Figure 12: Nitrogen and Total Leaf Cation from B Group origins
at 5 - 7 years old**



MINERAL NUTRITION X GENOTYPE INTERACTION

In our comments on mineral nutrition, it appears obviously that some origins from both groups are presenting some “permanent” characteristics. Table 12 showing correlation for mineral leaf content at 3 years old and at 5 – 7 years old is confirming this fact.

TABLE 12: CORRELATION BETWEEN YEAR 3 AND ADULT STAGE

	A	B
	Group	Group
Nitrogen	0,81	0,82
Phosphorus	0,64	0,74
Potassium	0,89	0,95
Calcium	0,87	0,94
Magnesium	0,88	0,84

This very highly significant relationship ($r > ***$) allows to study population structures in both the groups. For that matter the following variables that seem very characteristic are used:

- Nitrogen (%), K/TLC (%), Ca/TLC (%), Mg/TLC (%) and Chlorine (%)
- Chlorine is available only for 5 – 7 years old data.

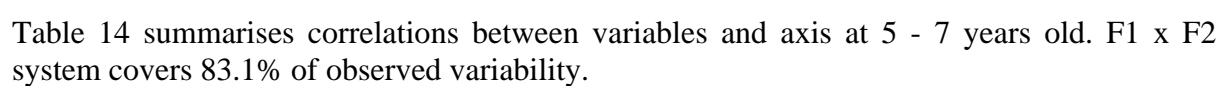
For A group of origins, all families are used at 3 and 5 – 7 years old. For B group origins, only legitimate families are scrutinized.

Analyse of A Group origin population

Table 13 summarises correlations between variables and axis at 3 years old. F1 x F2 system covers 86.9% of observed variability.

TABLE 13: CORRELATIONS BETWEEN VARIABLES AND AXIS

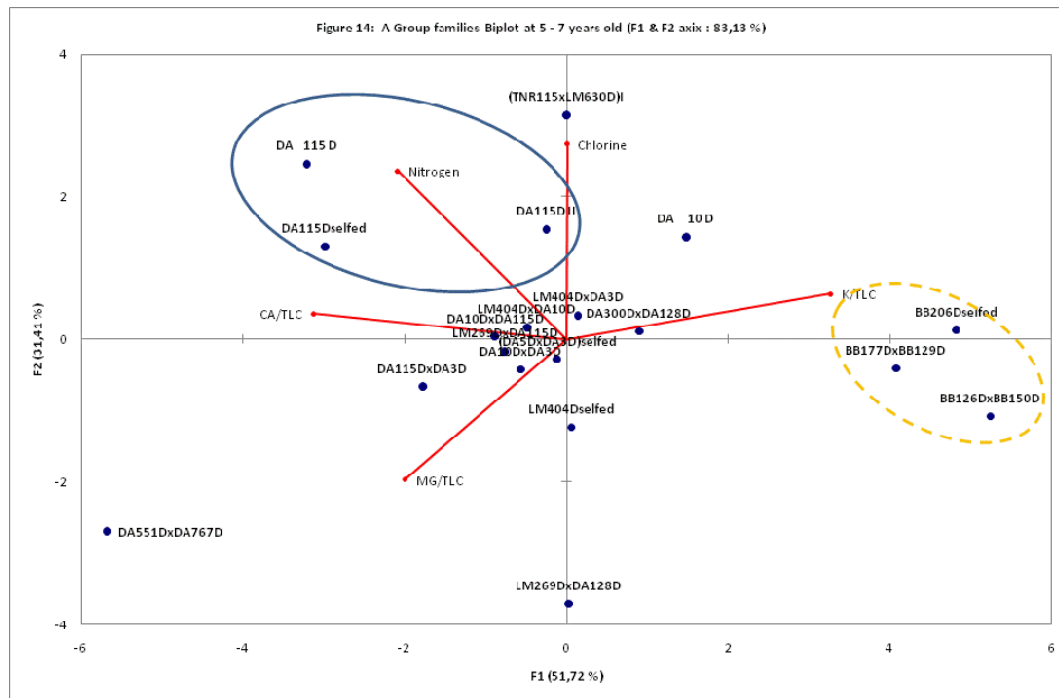
	F1	F2	F3
Nitrogen	0,697	-0,425	0,578
MG/TLC	0,146	0,952	0,269
CA/TLC	0,945	-0,126	-0,303
K/TLC	-0,942	-0,293	0,166



	F1	F2	F3	F4
Nitrogen	-0,627	0,707	-0,157	0,287
MG/TLC	-0,599	-0,592	0,521	0,141
CA/TLC	-0,938	0,107	-0,266	-0,196
K/TLC	0,977	0,191	-0,039	0,083
Chlorine	0,003	0,820	0,555	-0,139

	F1	F2	F3	F4
Nitrogen	-0,627	0,707	-0,157	0,287
MG/TLC	-0,599	-0,592	0,521	0,141
CA/TLC	-0,938	0,107	-0,266	-0,196
K/TLC	0,977	0,191	-0,039	0,083
Chlorine	0,003	0,820	0,555	-0,139

Introduction of Chlorine as new variable is reversing direction of other vectors (Figure 14). DA115D and its selfings are stably isolated (blue circle). The other DA115D based families are joining a larger deli group in centre of the graph. Socfindo Deli families are also fixed together along F2 positive extremity (orange dashed circle).



TNR115 x LM630D (very low Mg / TLC), and LM269D x DA128D and DA551D x DA767D in opposite (very high Mg / TLC) are maintaining their respective position.

The case of DA115D and its selfing derivatives versus Socfindo deli families is interesting to scrutinize: in fact, for DA115D, Nitrogen, Calcium and Chlorine are high and Potassium is low. But potassium nutrient is delivered by Potassium Chlorine. It is possible to imagine that this genotype is absorbing easily chlorine cation which pulls Calcium with it. In reverse, Socfindo Deli families do not absorb too much Chlorine, then Calcium, allowing Potassium to enter massively in the leaflets.

Looking at Socfindo commercial planting materials, it is possible to isolate three groups that may need specific nutritional management:

- K-N+Ca+: DA115D
- K+N-Ca-: BB206D, BB126DxBB150D and BB177DxBB129D
- Medium: DA5DxDA3D, DA10DxDA115D, DA115DxDA3D, DA300DxDA128D, LM404Dselfed, LM404DxDA10D and LM404DxDA3D

DA10DxDA115D and DA115DxDA3D should be considered as K-N+Ca+ at immature stage.

In other hand, 3 families are very far from previous groups: TNR115 x LM630D at F1 positive extremity, LM269D x DA128D at F1 negative extremity and DA551D x DA767D in external part of negative F1-F2 quarter.

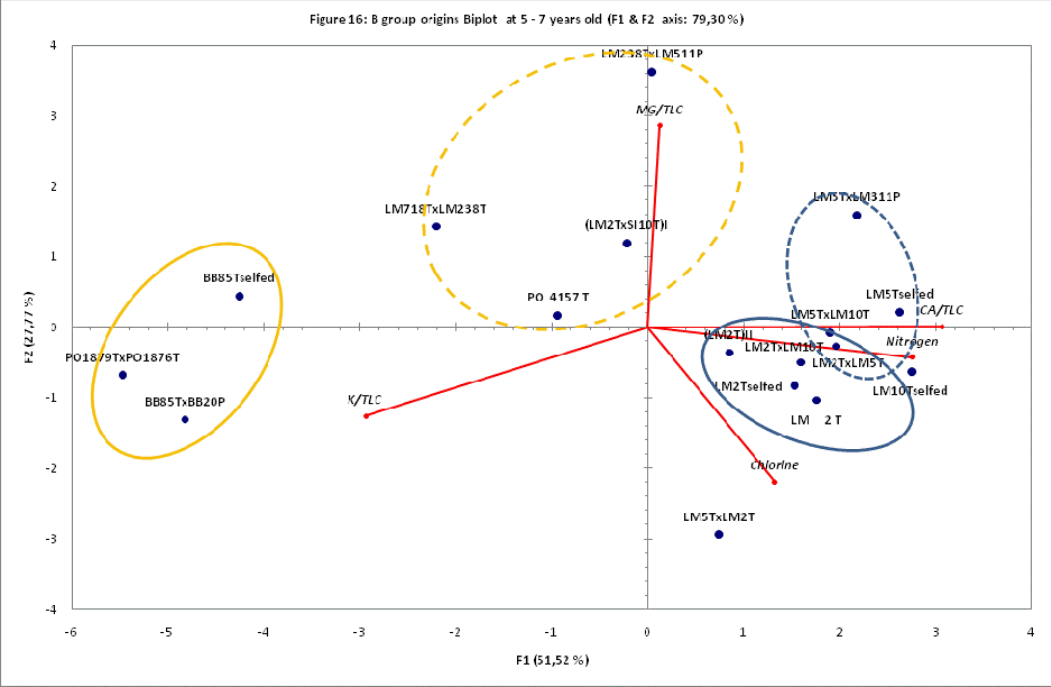
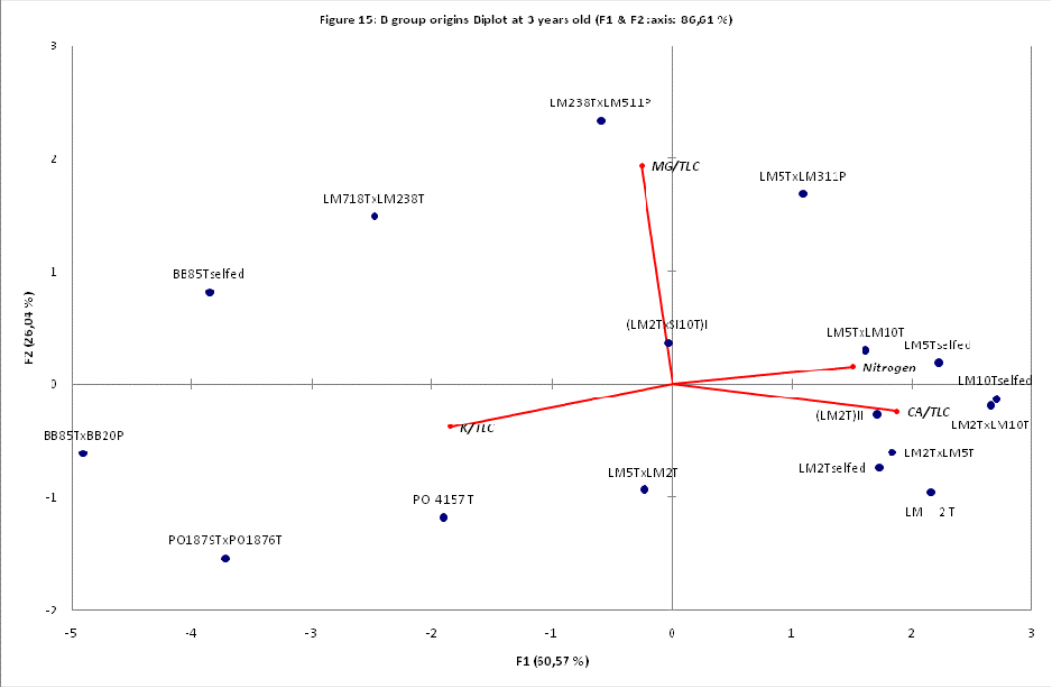
Analyse of B Group origin population

Table 15 summarises correlations between variables and axis at 3 years old. F1 x F2 system covers 86.6% of observed variability.

At 3 years old, Nitrogen and Ca / TLC vectors are very narrow as for A group origins. Position of different origins is well regrouped for La Mé origins and not that for other ones. But, it is possible to say that in average these La Mé origins belong to positive F1 axe (N+Ca+) and Yangambi / Nifor / Kuala Krapuh origins to negative F1 axe (N-Ca-). It seems that LM2T deriving families are more Mg- and LM5T deriving families are more Mg+.

TABLE 15: CORRELATION BETWEEN VARIABLES AND AXIS AT 3 YEARS OLD

	F1	F2	F3
Nitrogen	0,770	0,080	0,633
Mg/TLC	-0,130	0,991	-0,030
Ca/TLC	0,961	-0,122	-0,250
K/TLC	-0,944	-0,195	0,266



At 5 – 7 years old, introduction of Chlorine variable is précising this behaviour (Figure 16). La Mé group is Cl+Ca+ and Yangambi / Nifor / Kuala Krapuh origins are Cl-Ca-. It seems that La Mé sub-group, particularly LM2T and relatives, is functioning as DA115D and deriving origins. 4 group of nutrition could be easily identified:

- Nifor / Kuala Krapuh families (orange circle): K+N-Ca-Cl-
- Yangambi families (dashed orange circle): K+ N-Ca-Cl-Mg+
- LM2T and deriving origins (blue circle): K-N+Ca+Cl+
- LM5T and deriving families (dashed blue circle): K-N+Ca+Cl+Mg+

In addition, LM10T and deriving families are intermediate between LM2T and LM5T

MINERAL NUTRITION AND CROP

Results from two specific trials (ALCP 61 and ALCP 62) are scrutinized as explained previously. These two trials were the base to prove that mineral content critical level in the leaf could differ from one type of planting material to another (Jacquemard *et al*, 2002). These two experiments differ only by B Group pedigree: pollens used for ALCP 61 materials come from LM2T selfing and those for ALCP 62 come from LM311P itself. LM311P is deriving from LM2T by open pollination.

Despite this very narrow B group ancestors, nutrient levels are quite contrasted (Table 16):

TABLE 16: AVERAGE MINERAL CONTENTS AND CROP FOR ALCP 61 AND ALCP 62

		Leaf N	Leaf P	Leaf K	Leaf Ca	Leaf Mg	Leaf Cl
(DA5D x DA3D) x LM2T selfed	AL61	2,551	0,156	0,987	0,856	0,154	0,630
(DA5D x DA3D) x LM311P	AL62	2,490	0,148	0,851	0,819	0,215	0,716
		Rachis P	Rachis K				
(DA5D x DA3D) x LM2T selfed	AL61	0,076	2,34				
(DA5D x DA3D) x LM311P	AL62	0,061	2,14				
		TLC	K/TLC	Mg/ TLC	Ca/TLC		
(DA5D x DA3D) x LM2T selfed	AL61	80,6	31,4	15,7	52,9		
(DA5D x DA3D) x LM311P	AL62	80,3	27,2	22,0	50,8		
		NB/p/yr	FFB / kg palm	AWB kg	CPO/ t / ha		
(DA5D x DA3D) x LM2T selfed	AL61	12,4	208,2	17,0	6,84		
(DA5D x DA3D) x LM311P	AL62	10,1	191,4	19,2	6,42		

LM311P is inducing much lower contents in leaf for Nitrogen, Phosphorus and Potassium and higher level in Magnesium and Chlorine. In term of production, ALCP 61 is characterized by a larger number of smaller bunches per year.

Table 17 is summarizing all statistical main effects on Rachis, Leaf mineral contents and production data. Rachis and leaf mineral contents are concerning 2008 campaign. Bunch number (BN), FFB (kg / tree), Average Bunch Weight (ABW; kg) and CPO (t / ha) are concerning 2006 / 2007 campaign that is the last recorded campaign. Significant differences are highlighted in bold and very significant in italic bold underlined police. Phosphorus application is depressing potassium contents in leaf (ALCP 61 and ALCP 62) and rachis (ALCP 62). It increases Phosphorus contents in leaf and rachis in both the experiments. It increases crop (FFB, ABW and CPO) in ALCP 62.

Nitrogen application is increasing Nitrogen (ALCP 61 & 62) and Potassium leaf content (ALCP 61). It is depressing Magnesium leaf content in ALCP61.

Potassium application increases potassium contents in leaf and rachis, but depresses Magnesium leaf contents in ALCP 61 only.

At least, Magnesium application is increasing leaf contents in ALCP 61 and crop (BN, FFB and CPO) in ALCP 62.

TABLE 17: RACHIS AND LEAF CONTENT, AND PRODUCTION DATA MAIN EFFECTS

Trial	Effect	Niv	Rachis P 08	Rachis K 08	Leaf N 08	Leaf P 08	Leaf K 08	Leaf Mg 08	BN 06_07	FFB 06_07	ABW 06_07	CPO 06_07
ALCP 061	Niv_P	0	0.060	2.62	2.547	0.151	<u>1.041</u>	0.147	12.0	200.7	16.9	6.64
		1	0.073	2.28	2.557	0.156	<u>0.976</u>	0.155	12.5	208.3	16.7	6.80
		2	0.096	2.11	2.551	0.160	<u>0.942</u>	0.161	12.6	215.5	17.3	7.09
	Niv_N	0	0.083	2.38	2.494	0.154	<u>0.941</u>	<u>0.161</u>	12.5	210.4	17.0	6.96
		1	0.074	2.22	2.571	0.156	<u>0.982</u>	<u>0.155</u>	12.4	206.5	16.9	6.80
		2	0.072	2.41	2.590	0.156	<u>1.037</u>	<u>0.147</u>	12.3	207.6	16.9	6.76
	Niv_K	0	0.071	1.64	2.579	0.157	0.894	<u>0.178</u>	12.2	207.4	17.2	7.01
		1	0.079	2.17	2.540	0.156	0.965	<u>0.155</u>	12.5	212.0	17.0	6.86
		2	0.079	3.20	2.534	0.154	1.100	<u>0.130</u>	12.4	205.1	16.7	6.66
	Niv_Mg	1	0.079	2.37	2.529	0.155	1.001	0.134	12.3	205.9	16.9	6.76
		2	0.074	2.30	2.574	0.157	0.972	0.175	12.4	210.4	17.1	6.92
ALCP 062	Niv_P	0	0.053	<u>2.45</u>	2.485	0.142	<u>0.876</u>	0.216	9.4	173.0	18.6	5.84
		1	0.060	<u>2.12</u>	2.473	0.147	<u>0.851</u>	0.215	10.3	194.4	19.0	6.48
		2	0.069	<u>1.85</u>	2.514	0.154	<u>0.828</u>	0.213	10.6	207.0	19.9	6.93
	Niv_N	0	0.066	2.21	2.419	0.145	0.822	0.222	10.3	191.0	18.6	6.41
		1	0.059	2.00	2.523	0.150	0.857	0.213	10.6	205.2	19.7	6.82
		2	0.057	2.21	2.530	0.147	0.876	0.210	9.3	178.2	19.2	6.02
	Niv_K	0	0.058	1.78	2.498	0.147	0.836	0.229	9.8	185.4	19.2	6.34
		1	0.067	2.11	2.507	0.151	0.840	0.213	10.6	202.6	19.3	6.79
		2	0.058	2.52	2.467	0.145	0.878	0.202	9.9	186.3	19.0	6.13
	Niv_Mg	0	0.061	2.15	2.491	0.147	0.858	0.211	9.8	185.0	19.2	6.24
		1	0.061	2.13	2.490	0.148	0.845	0.218	10.4	197.9	19.2	6.60

A regression analysis done according Foster method gives the following trend for both the trials:

(DA5D x DA3D) x LM2T selfed (Table 18):

In such planting material, very high yield is obtained without fertiliser and optimum crop is reached with the maximum rates of fertilizers (nearly 8 tones CPO / ha / year but 7.3t is reached with only 0.5kg of Kieserite).

TABLE 18: MULTIPLE REGRESSION ON ALCP 61 RESULTS

Treatments				CPO / ha / yr
N	P	K	Mg	
0	0	0	1	7.34
0	0	0	2	7.50
2	2	0	2	7.86
2	2	2	2	7.96

(DA5D x DA3D) x LM311P (Table 19):

Results appear more contrasted with ALCP 62. The yield is lower without fertilizer, but response to Phosphorus is vigorous (1.4 tons CPO / ha / year). Highest rate of phosphorus fertilization gives optimum yield (7.68 tons CPO / ha), but increasing Nitrogen and / or Potassium is depressing strongly the yield by more than 1 tons CPO / ha.

TABLE 19: MULTIPLE REGRESSION ON ALCP 62 RESULTS

Treatments				CPO / ha / yr
N	P	K	Mg	
0	0	0	0	6.23
0	0	1	0	6.56
0	0	1	1	(6.83)
0	1	1	0	6.93
0	1	1	1	7.21
1	1	1	1	7.57
1	2	1	1	7.68
1	2	2	1	6.61
2	2	2	1	6.12

Finally, (DA5D x DA3D) x LM2T selfed material could reach nearly 8 tons CPO / ha, the corresponding total fertilizer rate is attaining 8.5 kg. The optimum potential of (DA5D x DA3D) x LM311P reaches 7.7 tons CPO / ha, but corresponding total fertilizer rate is only 4 kg per tree, saving particularly 2 kg in Urea and Potassium Chlorine. However 311P appears to be hungrier for P than LM2T and 1.5 kg RP does not appear sufficient to fulfil 311P phosphorus requirements. Adding more N or K does not improve the yield as P is the most limiting factor which will need to be corrected before any effect of N or K can be seen.

LM311P as ancestor has been regularly cited in association with LM5T for its particular behaviour in mineral nutrition. Results presented above, should be confirmed with more experiments. But they are clear food for thought that some material could better use specific nutrient than others, and there is a very wide scope of investigation to adapt specific material to specific natural resources.

CONCLUSION

According this short study, it appears that in PT Socfindo germplasm, Deli group ancestor families and African ancestor families could be gather together within specific groups corresponding to their relative leaf nutrient contents: particularly families deriving from DA115D, BB206D from A group, LM5T, LM311P and Yangambi sources from B group present very specific characteristics.

According comparison from Aek Loba Timur Bloc and commercial plantings, some families with DA115D or BB206D, for example, could have different nutritional behaviour according calcium context.

The interesting relationship between Nitrogen and Total Leaf Cation proposed by Foster on DAMI materials should be studied more deeply on more compact materials like Deli x La Mé ones.

After proving genetic influence on critical level, new analyses realised on two fertiliser trials at Aek Loba give food for thought that fertilisation management should be apprehended in taking into account the origin of material and this might be even more important in the future if cloning material is used.

In that matter, PT Socfindo is implementing specific experiment studying mineral nutrition – genotype interaction focusing on nitrogen and potassium nutrition and fertilisation with ancestors that have contrasted behaviour as shown in this paper.

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Annex 1

Fertilisation tables for Aek Loba Timur progeny trials at immature stage

Application in kg / tree / year of element equivalent

1995 plantings

Elements	N0 / N1	N2	N3
Nitrogen	0.478	0.460	0.805
Phosphorus (P ₂ O ₅)	0.448	0.315	0.158
Potassium (K ₂ O)	0.360	0.450	0.450
Magnesium (MgO)	0.156	0.195	0.000
Boron (B ₂ O ₅)	0.024	0.046	0.046

1997 April plantings

Elements	N0 / N1	N2	N3
Nitrogen	0.634	0.722	1.150
Phosphorus (P ₂ O ₅)	0.525	0.263	0.175
Potassium (K ₂ O)	0.540	1.560	1.200
Magnesium (MgO)	0.120	0.200	0.100
Boron (B ₂ O ₅)	0.046	0.041	0.046

1997 Oct – Nov plantings

Elements	N0 / N1	N2	N3
Nitrogen	0.478	0.549	1.150
Phosphorus (P ₂ O ₅)	0.448	0.263	0.175
Potassium (K ₂ O)	0.360	1.440	1.200
Magnesium (MgO)	0.125	0.260	0.130
Boron (B ₂ O ₅)	0.026	0.041	0.046

1998 May planting

Elements	N0 / N1	N2	N3
Nitrogen	0.651	1.150	1.150
Phosphorus (P ₂ O ₅)	0.519	0.175	0.000
Potassium (K ₂ O)	1.004	1.200	0.600
Magnesium (MgO)	0.202	0.100	0.100
Boron (B ₂ O ₅)	0.037	0.046	0.046

1998 Oct – Nov plantings

Elements	N0 / N1	N2	N3
Nitrogen	0.362	0.759	1.265
Phosphorus (P ₂ O ₅)	0.460	0.263	0.000
Potassium (K ₂ O)	0.192	1.440	1.200
Magnesium (MgO)	0.096	0.200	0.100
Boron (B ₂ O ₅)	0.015	0.041	0.046

1999 March – April plantings

Elements	N0 / N1	N2	N3
Nitrogen	0.251	1.035	1.380
Phosphorus (P ₂ O ₅)	0.286	0.263	0.350
Potassium (K ₂ O)	0.617	1.440	1.320
Magnesium (MgO)	0.137	0.200	0.300
Boron (B ₂ O ₅)		0.041	0.046

2000 April – May plantings

Elements	N0 / N1	N2	N3
Nitrogen	0.268	1.196	1.288
Phosphorus (P ₂ O ₅)	0.263	0.300	0.300
Potassium (K ₂ O)	0.065	1.080	1.320
Magnesium (MgO)	0.043	0.180	0.300
Boron (B ₂ O ₅)	0.008	0.076	0.103

Annex 2

Leaf Cation balance data

Leaf cation balance data for A group origins at 3 years old at ALT Bloc

Sub-Group	A origin	TLC	MG	MG/TLC	CA	CA/TLC	K	K/TLC
AN x Socfin	(TNR115xLM630D)I	95,1	15,7	16,5%	53,3	56,0%	26,1	27,4%
Socfindo	BB126DxBB150D	92,2	17,0	18,5%	45,4	49,2%	29,8	32,3%
	BB177DxBB129D	92,0	15,6	17,0%	49,2	53,5%	27,2	29,5%
	BB206Dselfed	93,2	16,9	18,1%	48,2	51,7%	28,2	30,2%
Dabou	(DA5DxDA3D)selfed	101,7	21,2	20,8%	58,7	57,7%	21,9	21,5%
	DA 10 D	97,4	16,0	16,4%	56,1	57,6%	25,3	26,0%
	DA10DxDA3D	95,5	17,9	18,7%	54,9	57,4%	22,8	23,9%
	DA10DxDA115D	102,8	19,4	18,9%	61,2	59,6%	22,1	21,5%
	DA 115 D	107,0	19,9	18,6%	66,9	62,5%	20,2	18,9%
	DA115D II	106,3	17,7	16,6%	66,5	62,5%	22,1	20,8%
	DA115Dselfed	104,0	19,6	18,8%	63,6	61,2%	20,8	20,0%
	DA115DxDA3D	100,8	19,2	19,0%	61,8	61,4%	19,8	19,6%
Socfin x Dabou	LM269DxDA115D	101,9	17,4	17,1%	62,7	61,5%	21,7	21,3%
	LM269DxDA128D	98,6	22,2	22,5%	53,4	54,1%	23,0	23,3%
Dabou	DA300DxDA128D	95,6	18,2	19,0%	54,7	57,2%	22,7	23,8%
	DA551DxDA767D	104,2	22,8	21,9%	62,0	59,5%	19,4	18,6%
Socfin	LM404Dselfed	97,3	19,2	19,7%	54,7	56,2%	23,4	24,1%
Socfin x Dabou	LM404DxDA10D	97,2	17,7	18,2%	56,1	57,7%	23,4	24,1%
	LM404DxDA3D	93,8	16,7	17,8%	53,5	57,0%	23,7	25,2%

Leaf cation balance data for A group origins at 5 – 7 years old at ALT Bloc

Sub-Group	A origin	TLC	MG	MG/TLC	CA	CA/TLC	K	K/TLC
AN x Socfin	(TNR115xLM630D)I	83,0	13,3	16,0%	43,9	53,0%	25,8	31,1%
Socfindo	BB126DxBB150D	80,2	14,1	17,5%	36,9	45,9%	29,3	36,5%
	BB177DxBB129D	80,3	12,4	15,5%	39,6	49,3%	28,3	35,2%
	BB206Dselfed	82,0	13,2	16,1%	39,0	47,6%	29,8	36,4%
Dabou	(DA5DxDA3D)selfed	87,1	16,0	18,3%	45,4	52,1%	25,8	29,6%
	DA 10 D	83,6	13,3	16,0%	42,8	51,2%	27,5	32,9%
	DA10DxDA3D	83,3	13,8	16,6%	45,2	54,2%	24,3	29,2%
	DA10DxDA115D	86,0	15,0	17,4%	46,7	54,3%	24,3	28,3%
	DA 115 D	90,3	16,0	17,8%	50,8	56,3%	23,4	25,9%
	DA115D II	84,7	14,1	16,6%	45,8	54,0%	24,9	29,4%
	DA115Dselfed	87,7	16,0	18,3%	49,0	55,9%	22,6	25,8%
	DA115DxDA3D	85,2	14,2	16,6%	48,8	57,3%	22,2	26,0%
Socfin x Dabou	LM269DxDA115D	85,1	14,8	17,4%	45,9	54,0%	24,3	28,6%
	LM269DxDA128D	86,2	17,0	19,8%	45,0	52,3%	24,1	28,0%
Dabou	DA300DxDA128D	83,6	15,6	18,6%	42,8	51,2%	25,3	30,2%
	DA551DxDA767D	91,1	21,4	23,5%	51,5	56,5%	18,3	20,0%
Socfin	LM404Dselfed	84,6	15,3	18,1%	45,0	53,2%	24,3	28,7%
Socfin x Dabou	LM404DxDA10D	85,2	14,9	17,5%	45,5	53,4%	24,8	29,1%
	LM404DxDA3D	82,1	13,5	16,4%	43,8	53,4%	24,7	30,1%

Leaf cation balance data for B group origins at 3 years old at ALT Bloc

Sub Group	B origin	TLC	MG	MG/TLC	CA	CA/TLC	K	K/TLC
LM	LM 2 T	101,2	17,5	17,3%	60,4	59,7%	23,2	23,0%
	LM2Tselfed	98,8	17,4	17,7%	58,7	59,4%	22,7	23,0%
	(LM2T)II	97,1	17,7	18,2%	56,6	58,3%	22,8	23,5%
	LM2TxLM10T	98,8	18,0	18,2%	58,9	59,6%	21,8	22,1%
	LM2TxLM5T	99,4	17,7	17,8%	58,7	59,0%	23,0	23,2%
	LM5TxLM2T	96,7	17,0	17,6%	56,0	57,9%	23,7	24,5%
	LM5Tselfed	102,3	19,3	18,8%	62,6	61,2%	20,4	20,0%
	LM5TxLM311P	104,6	21,8	20,8%	61,2	58,5%	21,6	20,7%
	LM5TxLM10T	97,4	18,5	19,0%	57,6	59,1%	21,3	21,9%
	LM10Tselfed	102,7	18,8	18,4%	62,3	60,7%	21,5	20,9%
LM x SI	(LM2TxSI10T)I	96,4	18,4	19,1%	53,1	55,1%	24,8	25,7%
SOCFINDO	BB85Tselfed	93,3	18,7	20,0%	44,9	48,1%	29,7	31,8%
	BB85TxBB20P	90,7	16,5	18,2%	43,1	47,5%	31,1	34,3%
YA	LM238TxLM511P	97,8	21,3	21,8%	53,3	54,5%	23,1	23,7%
	LM718TxLM238T	95,4	19,8	20,8%	48,9	51,2%	26,7	28,0%
	PO 4157 T	93,4	16,3	17,5%	52,6	56,4%	24,5	26,2%
NIFOR	PO1879TxPO1876T	93,6	15,9	17,0%	47,2	50,5%	30,5	32,6%
Other	PO 3660 P	100,3	23,6	23,6%	52,7	52,6%	23,9	23,9%
	BB 106 T	85,5	13,4	15,7%	44,6	52,2%	27,5	32,2%
	FR10	107,3	21,2	19,7%	67,2	62,7%	18,9	17,6%
	?xLM9T	94,1	19,1	20,3%	53,6	56,9%	21,5	22,8%
	FR9	107,6	21,3	19,8%	64,9	60,3%	21,4	19,9%
	LM426Tselfed	104,1	19,0	18,3%	60,8	58,4%	24,3	23,3%
	LM2TxLM231T	108,7	25,4	23,4%	62,3	57,4%	20,9	19,2%

Leaf cation balance data for B group origins at 5 – 7 years old at ALT Bloc

Sub Group	B origin	TLC	MG	MG/TLC	CA	CA/TLC	K	K/TLC
LM	LM 2 T	86,2	14,4	16,7%	46,0	53,3%	25,9	30,0%
	LM2Tselfed	83,7	14,0	16,7%	44,8	53,5%	24,9	29,7%
	(LM2T)II	83,0	14,2	17,2%	43,2	52,1%	25,5	30,8%
	LM2TxLM10T	84,5	14,0	16,6%	46,5	55,1%	24,0	28,4%
	LM2TxLM5T	85,0	14,3	16,8%	45,7	53,8%	24,9	29,3%
	LM5TxLM2T	83,2	12,4	14,9%	43,9	52,8%	26,8	32,2%
	LM5Tselfed	87,0	15,4	17,7%	49,0	56,3%	22,7	26,0%
	LM5TxLM311P	89,7	17,7	19,7%	48,4	53,9%	23,6	26,3%
	LM5TxLM10T	84,0	15,0	17,8%	45,6	54,3%	23,4	27,9%
	LM10Tselfed	86,5	14,1	16,3%	48,5	56,1%	23,9	27,7%
LM x SI	(LM2TxSI10T)I	83,6	16,0	19,2%	41,9	50,2%	25,6	30,6%
SOCFINDO	BB85Tselfed	80,3	15,1	18,8%	36,2	45,0%	29,1	36,2%
	BB85TxBB20P	80,5	14,2	17,6%	35,2	43,8%	31,1	38,6%
YA	LM238TxLM511P	86,8	18,3	21,0%	45,4	52,3%	23,1	26,6%
	LM718TxLM238T	83,8	16,0	19,1%	41,2	49,1%	26,6	31,7%
	PO 4157 T	85,6	15,0	17,5%	45,3	53,0%	25,2	29,5%
NIFOR	PO1879TxPO1876T	82,2	11,8	14,3%	39,1	47,5%	31,4	38,2%
Other	PO 3660 P	82,3	15,2	18,5%	40,1	48,7%	27,0	32,8%
	BB 106 T	75,9	11,1	14,6%	36,8	48,4%	28,1	37,0%
	FR10	88,6	18,5	20,9%	47,2	53,3%	22,9	25,8%
	?xLM9T	81,1	15,6	19,3%	41,5	51,2%	23,9	29,5%
	FR9	91,1	17,5	19,3%	50,0	54,9%	23,5	25,8%
	LM426Tselfed	86,5	15,0	17,3%	46,5	53,7%	25,0	28,9%
	LM2TxLM231T	92,0	18,8	20,5%	49,3	53,6%	23,9	25,9%

Leaf Cation balance data for A group families in Commercial plantings at 3 years old

Sub-group	A origin	TLC	K/TLC	Ca/TLC	Mg/TLC
SOCFINDO	BB126D x BB150D	95.2	29.6	46.6	23.8
	BB206D selfed	98.6	27.5	49.6	23.0
DABOU	DA115D selfed	92.4	27.1	45.7	27.2
	DA115D x (DA5DxDA3D)	94.4	30.5	46.4	23.2
	DA5D x DA3D	90.3	28.9	44.5	26.6
SOCFIN x DABOU	(DA5D x DA3D) x (LM404D x	89.6	28.4	45.6	25.9
	LM404D x (DA5DxDA3D)	97.6	25.5	53.4	21.1
	LM404D x DA10D	95.4	27.7	47.8	24.6
	LM404D x LM270D	94.4	29.4	40.5	30.1

Leaf Cation balance data for B group families in Commercial plantings at 3 years old

Sub-group	A origin	TLC	K/TLC	Ca/TLC	Mg/TLC
La Mé	LM2Tself	91.4	28.1	46.2	25.7
	LM5Tself	90.8	28.0	45.8	26.1
	LM5TxLM311P	93.6	24.0	50.1	25.9
Yangambi	LM718Tself	98.6	27.5	49.6	23.0
	LM718TxLM238T	94.7	29.5	42.6	28.0